(12) UK Patent Application (19) GB (11) 2 311 796 (13) A

(43) Date of A Publication 08.10.1997

(21) Application No 9706553.6

(22) Date of Filing 01.04.1997

(30) Priority Data
(31) 9606804 (32) 30.03.1996 (33) GB

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(51) INT CL^6
E21B 47/01

(52) UK CL (Edition O)
E1F FHU

(56) Documents Cited
GB 2253699 A GB 2178088 A GB 2043898 A
US 5022484 A

(58) Field of Search
UK CL (Edition O) E1F FHH FHU, G1G GMB
INT CL^6 E21B
Online: World Patents Index

(54) **Downhole sensor on extendable member**

(57) A downhole sensor 1 for receiving a surface generated signal, and a method of conducting a subsurface survey is described. The downhole sensor 1 is located on a body 2 in a well completion string, and is connected to the body 2 by a selectively extendable member 4, such that the downhole sensor 1 may be extended from the body 2 towards the inner surface of the well bore 3. Alternative embodiments include: the extendable member 4, in figure 2, can be a hinged arm 7 including shear pins for connection to the body 2; the extendable member 4, in figure 1, can have deflector plates 35, so that when the body 2 is inserted downhole, any contact with the well bore 3, pushes the sensor into the protection of the body 2; a memory device for logging data can be mounted on the body 2 in close proximity to the sensor 1; data can be uploaded from the memory device when requested, by computer software at the surface.

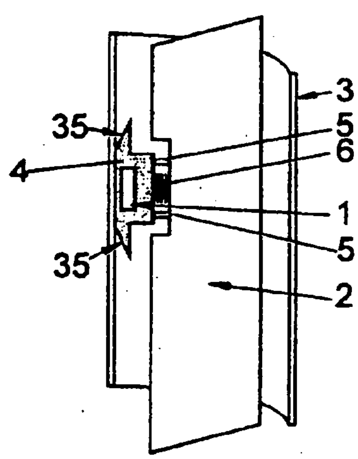

Fig. 1

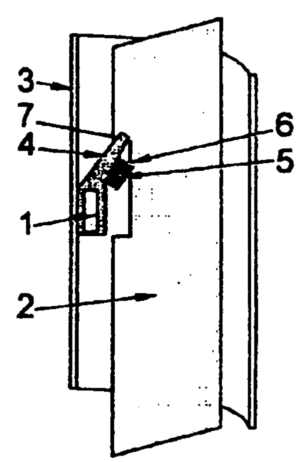

Fig. 2

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

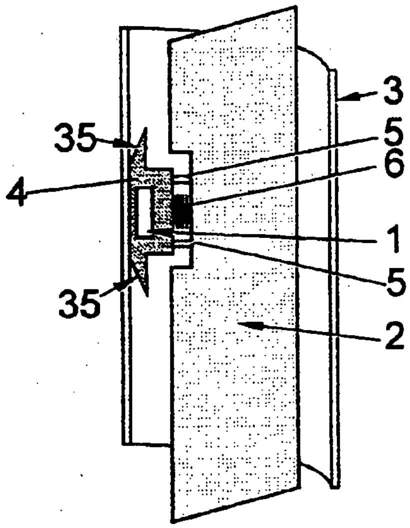

Fig. 1

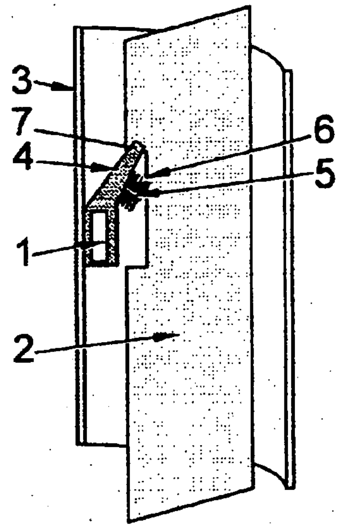

Fig. 2

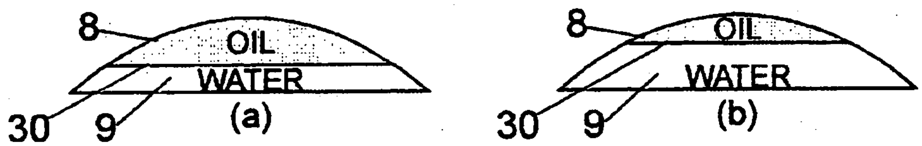

Fig. 3

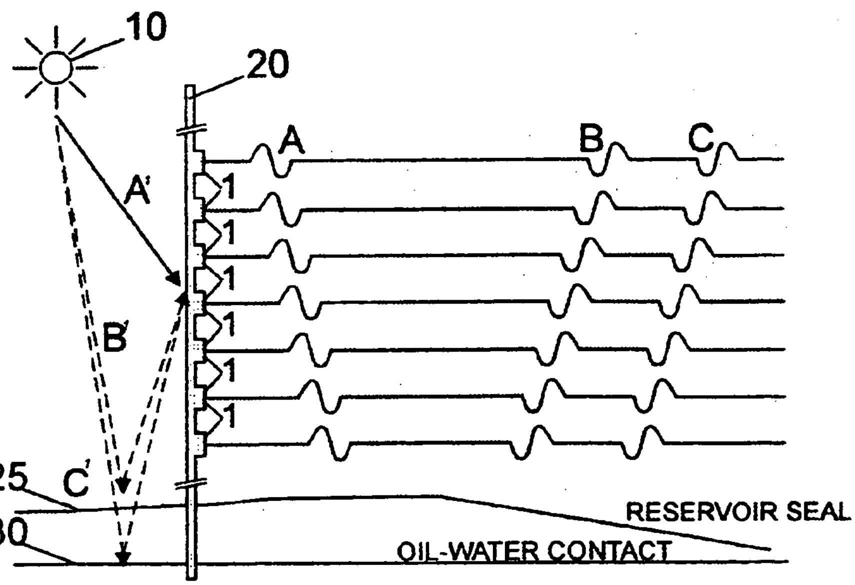

Fig. 4

Downhole Sensors

This invention relates to the use of downhole sensors, particularly but not exclusively to the use of permanently installed downhole seismic sensors for monitoring oil and gas reservoirs.

Traditionally the management and measurement of underground reservoirs has involved overground seismic survey techniques. For instance, with regard to offshore oil and gas reservoirs, a seismic survey will involve a surface ship, a sonar receiving array, and a sonar emitting device. The reservoir would typically be surveyed by emitting a signal from the sonar device, and receiving the return sonar signal in the sonar receiving array. To build up a three dimensional model of the reservoir the surface ship must make many longitudinal and transverse passes over the reservoir. A four dimensional seismic model can be developed by repeating the survey after some time has elapsed, allowing changes in the reservoir that have occurred with time to be observed; this can be used to update the reservoir model.

However this traditional overground seismic survey

technique has the limitation in that the obtainable resolution of subsurface events is relatively low at approximately 10 metres. This survey process can be improved through carrying out bore hole seismic surveys which allow accurate (time/depth) correlation as well as improved resolution, due to the reduced signal travel path being one way only. Further the filtering effects of the earth apply only once.

However bore hole seismic surveys are time-consuming and non-cost-efficient, as the well must be shut down in the case of a producing well. Further, specialist slim seismic tools are required for through-tubing surveys.

For efficient field reservoir management, it is desirable to be able to accurately monitor reservoir behaviour and to anticipate future performance. In order to achieve this it is necessary to monitor on an ongoing basis all fluid contact levels in the reservoir.

A first aspect of the present invention provides a downhole sensor wherein the sensor is located on a body in a well completion string, the sensor being connected to the body by means of a selectively extendable member such that the sensor in use may be selectively extended from the body towards the inner surface of the well bore.

A second aspect of the present invention provides a method of conducting a subsurface survey comprising the steps of providing a sensor connected to a body by means of a selectively extendable member; including the body in a well completion string; running the body on the well completion string into a borehole of a

formation until the sensor is located at a pre-determined position; extending the sensor outwardly from the body until a portion of the sensor is in solid, direct or indirect contact with a portion of the inner surface of the formation; and providing a signal for the sensor to detect.

Preferably, the sensor is a seismic sensor or geophone.

Preferably, a plurality of sensors are provided for connection to the body, and more preferably, the sensors are longitudinally spaced along the length of the body. Alternatively, several bodies, each containing a sensor, are longitudinally spaced in the completion well string.

Typically, the selectively extendable member includes an arm, and an extending means. The extending means may be for example a spring or hydraulic mechanism. Alternatively, the extending means may be a delay mechanism and preferably is a hydraulic delay mechanism. Alternatively, the extending means may be a combination of a spring mechanism and a hydraulic delay mechanism. Alternatively, the extending means may be mechanical, activated by wireline once the body is in place.

Typically, the selectively extendable member is connected to the body by a hinge or coupling device.

Typically, the hinge or the coupling device include shear pins for connection to the body.

Preferably, data collected from the sensor is stored in a memory device situated downhole in use, most preferably on the body in close proximity to the

sensor. Typically, the data is uploaded from the memory device, when requested by computer software and associated surface equipment on the surface. Communication between the computer software and associated surface equipment and the downhole body is preferably achieved by means of an electrical conductor strapped along the entire length of the well completion string.

The present invention has the advantage that by providing sensors that are capable of remaining permanently downhole, a greater degree of survey resolution is capable, in an efficient manner in terms of time, equipment, man power and cost.

An embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawing, in which:

Fig. 1 is a side view of an embodiment of the invention;
Fig. 2 is a side view of a further embodiment of the invention;
Figs. 3 (a) and (b) are a representation of the oil/water contact level rising with time; and
Fig. 4 is a representation of the signals output from permanently installed downhole seismic sensors in accordance with the invention.

Referring firstly to Fig. 1, a permanently installed downhole seismic sensor 1 or geophone is shown to be detachably connected to a mandrel 2. The seismic sensor is located within a pad 4 having a flush face which provides a solid contact with casing 3. In Fig. 1 the pad 4 is shown to be extended from a recess in the mandrel 2 and this shows the pad 4 and sensor 1 in

their in use position. However, during the running in of the mandrel 2 which is in line with a well completion string (not shown), the pad 4 and hence sensor 1 will be in an unextended position, that is the inner facing portion of the pad 4 will lie flush with the corresponding portion of the recess in the mandrel 2. The pad 4 and hence sensor 1 are only extended from the mandrel 2 when the pad 4 has reached its required sensing position. The pad 4 is connected to the mandrel 2 by two arms generally designated at 5 and is biassed into its extended position by a spring 6.

Fig. 2 shows a further embodiment of the present invention, in which the pad 4 and sensor 1 are coupled to the mandrel by way of a hinge 7 and a single arm 6.

Fig. 3 (a) and (b) shows the oil/water contact 30 level rising with time as the reservoir is depleted. The fluid faces in the reservoir are separated by gravity, and as oil 8 is produced from a reservoir the pore space previously occupied by the oil will be gradually replaced by water 9 from below.

To monitor the reservoir using the apparatus of the present invention, the following method may be employed.

Referring to Fig. 4, a seismic source 10 is fired at the surface. The seismic signal generated reaches the downhole seismic sensors 1 or geophones via the signal paths A′ B′ and C′ as shown in Fig. 4. Seismic reflections or events are caused by the seismic signal encountering a difference in acoustic impedance in the medium through which it travels. This can be due to differences in rock properties, or to differences in the fluid occupying the rock pore space. In Fig. 4 a

well completion string 20 has eight downhole seismic sensors 1 mounted in line with the well completion string 20.

Fig.4 also shows the output signals 40 of the seismic sensors 1 or geophones over an elapsed time period

Event A in the output signal 40 representations is due to the direct downgoing arrival at the downhole seismic sensors 1 or geophones, along signal path A', of the seismic signal generated by the seismic source 10. Events B and C are due to the upgoing reflections from the reservoir cap 25 and the oil/water contact 30 from the signal paths B' and C' respectively.

As the oil/water contact 30 progresses upwardly over a period of time as shown in Fig. 3, the oil/water contact 30 event C will move closer in time to event B, event B remaining stationary unless substantial subsidence has occurred. The difference in time between events B and C is related to the distance from the oil/water contact 30 to the reservoir cap 25, which can be derived from the acoustic impedance of the reservoir rock material and the difference in trace arrival time.

The processing required to achieve this is based on standard and well-known vertical seismic profile processing techniques. The optimal sensor 1 spacing is a function of the resolution obtainable under the particular conditions of the well. This obtainable resolution is dependent on a number of factors, including depth, the formation consolidation, gas presence, acoustic coupling achieved and casing cement quality.

Three dimensional information in the entire reservoir can be built up by installing a downhole seismic sensor system in multiple wells in a field. In the particular embodiment described above, a single seismic source 10 on the surface is used to provide the seismic signal, but higher resolution information may be obtained through the inclusion in the permanent downhole seismic sensor system of a downhole seismic source. This allows a signal to be measured which is not subject to the severe earth filtering effects of high frequency events. The higher frequency components of the signal provide improved resolution measurements.

The permanent downhole seismic sensor process described above is dependent on an adequate acoustic coupling between the formation and the downhole seismic sensor 1 or geophone. Given that the downhole seismic sensor 1 is run on the completion string 20 which is normally centralised within the well bore, it is important for the sensor 1 to maintain in good contact with the inner surface of the borehole, which will normally be through the casing 3. It is further important that the downhole seismic sensor 1 is decoupled from the mandrel 2 in order to avoid damping of the acoustic signal by any large mass (such as the mandrel itself) surrounding the downhole seismic sensor 1.

In the case of the embodiment shown in Fig. 1, the pad 4 may be run into the borehole on the well completion string 20 without damaging the seismic sensor 1 contained within the pad 4, as the angle of the pad 4 protector/deflector plates 35 can be chosen such that for a slightly non-uniform casing 3, the pad 4 is forced into the mandrel 2 and thus protected.

Alternatively, or in addition an orifice type hydraulic

delay mechanism may be used to allow running in hole with the pad retracted. With time, hydraulic oil escapes through an orifice and thus allows the pad 4 to extend.

Alternatively, or in addition, in order to extend or retract the downhole seismic sensor 1 from or into the mandrel 2, this mechanism may be activated by a wireline tool (not shown) run in after the well completion string 20. In the case of the downhole seismic sensor 1 shown in Fig. 2, this embodiment of the present invention provides a downhole seismic sensor 1 which does not require to be retracted if the mandrel 2 is to be pulled out of the hole.

Shear pins may be used to enable the well completion string 20 to be pulled free of the pad 4, should the pad 4 become stuck while running into or out of the hole.

Normally, seismic sensors 1 require high telemetry rates to the surface due to the large volumes of data acquired. In the embodiments of Figs. 1 and 2 a digital sensor interface is used in connection with a storage memory to collate the data received from the seismic sensors 1. The digital sensor interface (not shown) and memory (not shown) are located in close proximity to the seismic sensors 1, and in a preferred embodiment of the present invention there is one memory storage package (not shown) per downhole seismic sensor 1. The digital sensor interface and memory stores the data until it is interrogated by software from the surface, at which point transmission takes place. This is done for each seismic sensor 1 in sequence, until all the seismic sensors 1 have been read. This occurs for each shot of the seismic source 10. Once

transmission has occurred for each downhole seismic sensor 1 the system is ready for the next shot of the seismic source 10.

A series of shots would be taken during an acquisition operation, which are median stacked to reduce the level of noise recorded. The total number of shots per operation will depend on the data quality and prevailing conditions. Typically, five to eleven shots are required per stack.

The required frequency of acquisition operations is a function of the depletion rate of the reservoir.

Since the first break time is very stable, the acquisition window for each seismic sensor 1 can be configured with precision, to minimise the volume of data acquired. The sensors are fully programmable from surface using a digital acquisition system.

Modifications and improvements may be made within the scope of the present invention.

CLAIMS

1. A downhole sensor wherein the sensor is located on a body in a well completion string, the sensor being connected to the body by means of a selectively extendable member such that the sensor in use may be selectively extended from the body towards the inner surface of the well bore.

2. A downhole sensor according to claim 1, wherein the selectively extendable member includes an arm, and an extending means.

3. A downhole sensor according to either claim 1 or claim 2, wherein the selectively extendable member is connected to the body by a hinge.

4. A downhole sensor according to claim 3, wherein the hinge includes shear pins for connection to the body.

5. A downhole sensor according to any of the preceding claims, wherein data collected from the sensor is stored in a memory device situated downhole in use.

6. A downhole sensor according to claim 5, wherein the memory device is mounted on the body in close proximity to the sensor.

7. A downhole sensor according to either claim 5 or claim 6, wherein the data is uploaded from the memory device, when requested by computer software and associated surface equipment on the surface.

8. A downhole sensor according to claim 7, wherein

communication between the computer software and associated surface equipment and downhole body is achieved by means of an electrical conductor strapped along the entire length of the well completion string.

9. A method of conducting a subsurface survey comprising the steps of providing a sensor connected to a body by means of a selectively extendable member; including the body in a well completion string; running the body on the well completion string into a borehole of a formation until the sensor is located at a pre-determined position; extending the sensor outwardly from the body until a portion of the sensor is in solid, direct or indirect contact with a portion of the inner surface of the formation; and providing a signal for the sensor to detect.

10. A method according to claim 9, wherein data collected from the sensor is stored in a memory device situated downhole in use.

11. A method according to claim 10, wherein the memory device is mounted on the body in close proximity to the sensor.

12. A method according to either claim 10 or claim 11, wherein the data is uploaded from the memory device, when requested by computer software and associated surface equipment on the surface.

13. A method according to claim 12, wherein communication between the computer software and associated surface equipment and the downhole body is achieved by means of an electrical conductor strapped along the entire length of the well completion string.

14. A downhole sensor as hereinbefore described with reference to, and as shown in, any one of the accompanying Figs.

15. A method of conducting a subsurface survey as hereinbefore described with reference to, and as shown in, any one of the accompanying Figs.

The Patent Office

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Application No:	GB 9706553.6	**Examiner:**	Richard Jupp
Claims searched:	1-15	**Date of search:**	20 June 1997

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): E1F: FHH, FHU
G1G: GMB

Int Cl (Ed.6): E21B

Other: Online: World Patents Index

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2253699 A	(INSTITUT FRANCAIS DU PETROLE) whole document relevant	1-15
X	GB 2178088 A	(GEARHART TESEL LIMITED) whole document relevant	1-15
X	GB 2043898 A	(INSTITUT FRANCAIS DU PETROLE) whole document relevant	1-15
X	US 5022484 A	(SCHLUMBERGER TECHNOLOGY) whole document relevant	1-15

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&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.